Asian Elephant (*Elephas maximus*) and Riparian Wildlife Corridors: A Case Study from Lesser-Himalayan Zone of Uttarakhand

Ritesh Joshi [*], Rambir Singh [**]
[*] G. B. Pant Institute of Himalayan Environment and Development, Garhwal Unit, Srinagar, Garhwal - 246 174, Uttarakhand, India
ritesh_joshi2325@yahoo.com
[**] ESS Division, Department of Science and Technology, Govt. of India, Technology Bhavan, New Mehrauli Road, New Delhi, 110016, India
rambir@yahoo.com

Abstract: Developmental activities are increasingly recognized as the cause of habitat fragmentation and shrinking of wildlife corridors. This study assessed the status and importance of the Chilla – Motichur and Khara – Anjani riparian wildlife corridor in northern India. We review the potential involvement of developmental activities in the recent past, which has affected frequent movement of Asian elephant (*Elephas maximus*) within their home range. These corridors linking the Chilla forest with Motichur forest and Shyampur forest are subjected to severe anthropogenic pressures. Livestock grazing, fuel wood collection and movement of people are the major activities observed in both corridors. These anthropogenic activities have substantially affected the movement of elephant within their home range and have led to the loss of forests connectivity. The long-term effects will include genetic isolation, habitat fragmentation within the same forest and enhancement in the human-elephant conflict in adjoining areas. Genetic isolation of elephant populations may also increase the chances of replacement of inter-breeding to intra-breeding, and thereby reduce the population persistence even for wide ranging wildlife species. Additionally, minimization of all kinds of biotic pressures in the corridor areas and providing higher protection to riparian wildlife corridors are highly recommended. [THE JOURNAL OF AMERICAN SCIENCE. 2008;4(1):63-75]. (ISSN: 1545-1003)

Key Words: Asian elephant, *Elephas maximus*, riparian wildlife corridors, conservation, developmental activities, Rajaji National Park.

Introduction

The Shivalik foothills are one of the world's most spectacular landscapes, encompassing the tall grasslands and the *Shorea robusta* (Sal) forests. This entire belt is natural home of Asian elephants (*Elephas maximus*) besides many other wild animals like *Panthera tigris* (tiger), *Panthera pardus* (leopard), *Melursus ursinus* (Sloth bear), *Hyaena hyaena* (Hyaena), *Muntiacus muntjak* (Barking deer), *Axis axis* (Spotted deer), *Cervous unicolor* (Sambhar), *Sus scrofa* (Wild boar), *Ophiophagus hannah* (King cobra) etc. It is interesting to mention here that this protected area is western-most limit of Asian elephant, tiger and king cobra.

The Shivalik landscape is one of the last few places in the world where elephants exist and offers urgent need for conservation. This protected area in India's lesser Himalayan region falls under sub tropical moist deciduous forest type with extensive stands of *Shorea robusta* (Sal), *Mallotus phillipinensis* (Rohini), *Acacia catechu* (Khair), *Adina cordifolia* (Haldu), *Terminalia bellirica* (Bahera), *Terminalia* tomentosa (Sain), *Ficus bengalensis* (Bar), *Dalbergia sissoo* (Shisham) etc. in its premise besides many other important fodder plant species. From conservation point of view it appears to be India's one of the most successful national park and its development has helped to boost the population of Asian elephant in their natural habitat.

The natural continuous forest ranges of India has been broken up into many parts due to agriculture, urbanization, increasing road traffic and development related activities as well as other anthropogenic activities. This situation creates many problems for various organisms living in forests. Genetic isolation, limitation of dispersal and migration and the decline of populations of animals requiring large territories are the most common problems connected with fragmentation of forests and other components of the environment. A serious threat was also recorded to European wildlife resulting from the dynamic development of a transportation infrastructure network within the Trans-European Transportation Network (TEN-T) programme. This transportation network disrupts migration corridors of large terrestrial mammals

and causes a fragmentation of their environment on a scale not previously recorded (Nowak and Myslajek, 2005).

Elephants have suffered most grievously as compared to other wild herbivores on account of loss of their natural habitats and corridors as they require larger space for their various activities. Increasing human pressure inside the deeper forest regime and developmental projects has given rise to management and conservation problems. These include crop raiding by elephants outside the park area and even some human fatalities. The human population around the Rajaji National Park alone has doubled during past one decade and rapid urbanization and industrialization has resulted in the loss of many forestlands to townships and thereby increasing the major problem during the recent past. The present note is a part of our long term study on the behavioural biology of Asian elephant in sub tropical moist deciduous forests of India.

Methods

Study area

Rajaji National Park [29^0 15' to 30^0 31' North Latitude, 77^0 52' to 78^0 22' East Longitude] is spread over an area of 820.42 Km^2 in and around the Shivalik foothills, which lies in the lesser Himalayas and the upper Gangetic plains (Figure 1). Spread across Hardwar, Dehradun and Pauri districts of Uttarakhand state, Rajaji National Park (RNP) has been designated as a reserved area for the "Project Elephant" by the Ministry of Environment and Forests, Government of India with the sole aim of maintaining the viable population of Asian elephants in their natural habitat. The Shivalik foothills offer the most prominent geomorphic features of this tract. The river Ganges has cut across these hills at Hardwar. The Chilla forest area of the RNP lies in the east of the river Ganges and is attached by the Garhwal Forest Division. The study is ongoing in Hardwar (District-Hardwar), Chilla (District-Pauri) and Motichur (District-Dehradun) forest ranges of the RNP. Besides, few of the adjoining forest areas (Shyampur forest range of the Hardwar forest division) were also incorporated in this study. The altitude lies between 302-1000 m asl. The study site falls in sub-tropical moist deciduous forest type and landscape comprises of undulating hills with plain patches.

Data collection

For studying the movement pattern of elephants and analyzing the impact of developmental activities on riparian wildlife corridors and on elephant's movement, the Chilla – Motichur and Khara – Anjani corridors were surveyed in depthly from 2000 to 2007. The traditional movement tracks along with feeding grounds of elephants were searched and observed directly. Different forest blocks of concerned forest ranges were chosen one after another sequentially and searched for elephants for about 10 – 12 hours (depending upon weather conditions) in a single day search. The observations started at early hours in the morning being the best time to search and observe the elephant in open areas and four hours in the afternoon i.e. before the sunset. The data collected is as part of the animal monitoring activities. The daily record is based on direct sighting of animals, indirect evidences like feeding sign, footprints impression time and fresh dung piles. The direct sighting were noted in duly prepared proformas, recording the group composition, age and sex, if observed in groups and also the place of sighting, time and vegetation type. Besides, villagers of adjoining areas, Gujjars (where available), staff of forest department, the researchers from various scientific institutions and non-government organizations and other individuals working on this problem, were also interviewed. Field binocular was also used for observing their movement behaviour without disturbing the animal from an adequate and safe distance.

Identification of the elephants is important to verify their movement as in the same area there is a possibility that the same group was observed in the different forest beats. Therefore, distinctive features, with certain identification marks of individual elephants were noted like; shape of the ears, tusk size and shape, scars and tubercles on the body, tail length, total number of individuals (all ages separately), body mass and nature of group or solitary bull.

Results

Riparian wildlife corridors

Riparian zones are important migration corridors for migratory animals and due to annual flowing of water in various streams, these corridors also tend to be rich in nutrients and very diverse in both structural and vegetation characteristics, thus creating and sustaining a diversity of micro-habitats capable of

supporting many different wildlife species. Riparian corridors may provide safe travel routes between habitats reducing the negative impacts of forest fragmentation on wildlife populations. Riparian zones support high soil moisture and associated moisture-loving vegetation. These areas of high biological diversity often provide the necessary elements for survival. Because riparian corridors represent the area where upland and aquatic habitats merge, well-developed riparian corridors tend to contain a relatively high degree of wildlife diversity, having both upland-dependent and aquatic-dependent wildlife species present.

RNP comprises of several annual and perennial water streams and few of them are traditionally working as natural corridor for elephant's long-term migration. These riparian wildlife corridors generally comprise of mixed vegetation type and several important grass species were also present in between its edges. Ghasiram, Mundal, Soni, Dogadda, Siddh and Pili water streams and Binj and Rawasan rivers are few of the important riparian wildlife corridors, through which elephants interchange the forest zones. During hot period elephants use these corridors for resting purpose and for performing their movement towards river Ganges.

The corridor suitability was compared and analysed with different variables as settlements, road access, continuous forest patches, water bodies, religious places inside the protected area, fodder species and elephant movement over the corridor. It was observed during the course of study that presently only two major corridors, Chilla – Motichur and Khara – Anjani corridor are being utilized by elephants for their long-term migration. Both of these corridors are having rich fodder species in their premise and blessed with several annual rivers. Additionally Motichur, Song and Suswa rivers might act as alternative migratory route for elephants.

Movement is one of the most important ecological factors that represent the home range as well as habitat utilization of an animal. Both movement and migration depends upon the availability of natural food and water. Changes in season and scarcity of water and natural fodder species force wild animals to leave a place for few months and reached to new feeding grounds for fulfilling their feeding, water and other routine requirements. There are seasonal variations in fodder species as the area falls under sub-tropical moist deciduous forest vegetation type. Elephants use whole of the park area as their natural habitat but mostly they leave some of the areas having less vegetation cover and water for few months and move towards other ranges richer in fodder species and natural water. Although at that time few of them (mostly solitary bulls) use the same feeding grounds or move frequently in all the forest beats as a general rule of migration of any species.

Chilla forest range of the RNP and Shyampur forest range of the Hardwar forest division are well connected forest zone therefore; elephant utilizes both of these forest ranges round the year. These forests also provide connectivity to the Lansdowne forest division for elephant movement towards Corbett National Park. But during the recent past number of construction work along with huge amount of anthropogenic activities has restricted the frequent movement of elephants within their home range. It was observed during the present investigation that most of the elephants in these forest pockets do not represent their long-term migration mainly because of anthropogenic barriers present in between the forest areas. In the course of this study we have encountered many elephant groups and solo bulls and on the basis of their physical identity it was inferred that they are only restricted to move to some extent. In this area we have reported two major corridors, which are currently in use by the elephants.

The motor roads, which are adjacent to the forests like Hardwar-Dehradun National Highway, Hardwar – Bijnor National Highway, BHEL roads etc. have heavy traffic pressure. As per a preliminary study, the average number of vehicles passing on Dehradun-Hardwar road per day is 7,929 and all the wild animals, including elephants, are not in a position to cross this track at any time due to the presence of heavy traffic (Singh and Sharma, 2001). Same situation is with other corridors present adjacent to the RNP area. Kotdwar – Lansdowne road runs parallel to the river Kho and crosses the Rajaji-Corbett corridor, the major movement track of northwestern elephant population between the Yamuna and river Sharda. This road serves as the major transport link between Pauri town and Kotdwar area. The presence of traffic on the road, construction of steep retaining walls and the presence of human population along the entire corridor area have almost restricted the migration of elephants (Johnsingh and Williams, 1999).

Chilla – Motichur corridor

This corridor is about 7 kilometers long beginning at the tail end of Mundal valley and links the Chilla forest range on the eastern portion to the Motichur forest range on the west. Elephants used this corridor traditionally but currently elephants are not utilizing this corridor regularly. Sometimes solo bulls were

reported to follow this route and very occasionally group movements was also observed but only up to the island area, which is situated in between river Ganges. This corridor area comprises of many fodder plant species like *Mallotus phillipinensis* (Rohini), *Acacia catechu* (Khair), *Dalbergia sissoo* (Shisham), *Tectona grandis* (Teak), *Zizyphus mauritiana* (Ber), *Aegle marmelos* (Bel), *Ficus bengalensis* (Bar), *Ficus glomerata* (Gular), *Grewia oppositifolia* (Bhimal), *Bombax ceiba* (Semal), *Lannea grandis* (Jhingan), *Bauhinia variegata* (Kachnar), *Lagerstroemia parviflora* (Dhauri), *Kydia calycina* (Pula), *Syzygium cumini* (Jamun) and *Ehretia laevis* (Chamror). Besides, elephants also use various grasses and shrubs as their food resources, which include *Dendrocalamus strictus* (Bamboo), *Helicteres isora* (Kapasi), *Saccharum munja* (Pula), *Saccharum spontaneum* (Kans), *Cynodon dactylon* (Doob Grass), *Eulaliopsis binata* (Bhabhar Grass) etc. Presently Gujjars (tribal people) are completely relocated from Chilla and Motichur forest ranges of the RNP but the programme for resettling them to rehabilitation site from Gohri forest range is still ongoing.

Because, few of the forest pockets of the Gohri forest range also falls under this corridor area, therefore, it will be needed to resettle the Gujjars from this forest range. Elephant's movement was restricted in this area mainly due to biotic pressure and cattle grazing inside the forest area. Before 2002, we have observed large herds of elephants (maximum 38 elephants) in Kunao forest beat and in Binj river but presently their large groups have been subjected to dispersed in small ones.

There are four islands within the river in this region, which form part of the park. However, in the 1950's and 60's a number of developments, having drastic effect of land use came up on the western bank. The BHEL set up a major plant to the west of Ganges in the southern part of this trans-Ganga corridor for wildlife. Later the IDPL set up a large factory in the northern part of the corridor, also to the west of Ganga. The Army for a large ammunition dump has utilized the area in between and subsequently some remaining land was given away for the rehabilitation of Tehri Dam oustees. Thus, on the west bank most of the corridor stands diverted and rendered unusable.

On the east bank yet another major development activity has all, but destroyed the ecological corridor. A hydro-electric power project was set up in the 1970's. A barrage was constructed across the Ganga at Kunao just outside the park in the middle of the northern boundary. From here a deep power channel runs parallel to the east of Ganga for about 14 kilometers up to Chilla where the powerhouse is located. Although there are a couple of narrow bridges over the channel, these are not generally used by the animals. There have been cases of wild animals and even elephant mortalities, in attempts to cross these bridges.

Rarely elephant bulls and the group are known to cross, but otherwise there is complete isolation between western and eastern components of an internal ecological unit. The presence of army camp in the elephant corridor has also adversely affected the movement of wild animals. Besides, Khand village (48.5 hectares) is also located in the elephant migration corridor and is an obstacle to their movement. Ganga Bhogpur and Kaudia villages are also situated in eastern side of river Ganges and peripheral to Ganga canal. This area also lies under corridor area and elephants sometimes used to move in these villages in search of cultivated crops. Dudhia forest beat (island) due to its proximity to the Haripur Kala village is one of the most sensitive area as far as elephant casualties are concerned. During the study period occasionally, the movement of only solo bulls was observed in this part of the park. Group movement is almost restricted in this forest pocket mainly due to anthropogenic activities. Despite the fact that Dudhia area is rich in *Dalbergia sissoo* (Shisham) and *Acacia catechu* (Khair) forest, the preferred food item of the elephants. Besides, few of the fodder grass species like *Saccharum munja* and *Desmostachya bipinnata* are also grow in profusion in this area.

A major developmental project, which has divided the Rajaji – Corbett elephant habitat into two regimes is the 14 kilometers long Kunao – Chilla power channel, which was constructed on the east bank of river Ganges. In the early 1970s, this canal is 22 meter wide, nine meter deep and with full flow of water. The side of the canal is at an angle of 45^0 and cemented except for 500 meter; therefore, do not offer foot-hold to the elephants (Kumar, 1995). There are three places at which bull elephants and groups cross the power channel and go to Ganges.

1) Binj water stream – in Gohri forest range.
2) 60 meters long aqueduct connecting Dogadda with Ganges – in the edge of Gohri and Chilla forest ranges.
3) Bridge across the power channel, 2 kilometers from Chilla – in Chilla forest range (Soni Shroth).

In summer, bulls were observed more to use these tracks for their movements towards river Ganges but occasionally groups also follow this route, when their movement is towards western direction. Elephants generally use the Ghasiram water streams and Soni shroth bridge for interchanging these forest zones.

Khara – Anjani corridor

This corridor is about 5 kilometers long and connects the Khara forest beat of the RNP with Chandi, Siddh and Anjani forest beat (Shyampur forest range) of the Hardwar forest division. Presently this is one of the major corridor, which is regularly in use by elephants. The internal corridor area consists of the fodder species that Chilla forest comprises. The Anjani forest beat is attached with river Ganges and the forest comprises of *Acacia catechu, Dalbergia sissoo, Bombax ceiba, Helictres isora, Tectona grandis* and *Ficus bengalensis* trees. Besides, few of the important grass species are also present in the island area. During the last three years, state Government has constructed about four flyovers in Hardwar – Bijnor National Highway and due to this about 18 kilometers forest stretch along both the sides of the highway has got destructed mainly due to huge amount of anthropogenic activities. Besides, agricultural expansion adjoining to river Ganges has lead to the loss of forest wealth, which is also hindering the traditional movement of elephants.

It was observed during the present study that mostly adult bull elephants are utilizing this route. Sometimes few of the male elephants through associating, follow this route to enter the Anjani forest, which is peripheral to river Ganges. Elephants cross the national highway (Figure 2) and river Ganges in evening hours and re-enters to forest area in early morning hours. During this long journey elephants sometimes spent more time to feed on the plant species those are present in the island situated in between river Ganges. This forest stretch is one of the major corridor for elephant movement and presently has got disturbed mainly due to habitat loss around the national highway. Besides, elephants also utilize Gaziwali bridge, Shyampur bridge and Pili bridge those are situated over east Ganga canal for their outside movement and to feed on the cultivated crops in nearby villages. It was also observed during the study period that elephants also use the Ganga canal for fulfilling their water requirements.

During the study period all the villages suffering from crop raiding have been investigated. The affected villages are Jagjeetpur, Mishrpur, Panjneri, Ajeetpur and Jaipota in the western side of the conservation area and all these villages are situated peripheral to river Ganges. Villages Kangri, Ghaziwali, Shyampur, Sajanpura, Pili and Rasiabad are located peripheral to forest area and national highway whereas villages Gaindikhata, Lahadpur, Chiriapur, Vasuchandpur and Naurangabad are also situated adjacent to the forest area and national highway on south western direction of the conservation area. The villages along the river Ganges are situated on land that was once part of the elephant's home range. Therefore, the increasing elephant – man conflict is unfortunate but inevitable. The electric fence erected along with these villages and river Ganges has presently got damaged due to lack of proper maintenance. It was observed and inferred from the present investigation that elephants are utilizing their traditional feeding grounds in few of the areas, which are presently denied to them and are replaced by human settlements.

Once, all of these villages were better known for sugarcane cultivation and production but from last four years few of them have totally bunged the cultivation of sugarcane mainly due to fear of loss by elephants. These crop raids are the indications of attempts by some of the elephants to use their traditional routes leading to their feeding grounds, which are now denied to them and are replaced by human settlements. Gujjars are still living in Hardwar forest division and it was observed that most of their deras (shelters) are present in this corridor area. Elephants generally follow Siddh shroth river stretch for interchanging the forest areas and most of the Gujjar deras were situated in this part. Besides, one temple was also located in this forest stretch and the pressure of workers and visiting devotees sometimes caused hindrance in animal movement.

In the adjoining areas of Hardwar – Bijnor National highway various stakeholders has constructed shopping complexes, check posts, shrines, etc. and all of these spots are working as a barriers as far elephant's movement is concerned. Elephant's movement was quite frequent near to east Ganga canal and irrigation road especially during night period because this area comprises of bushes of *Dendrocalamus strictus* (Bamboo), which is a favourite food item of elephants. Whereas during the day hour biotic pressure is quite more in this route and cattle grazing is also a very common phenomenon observed in this part.

Elephant's movement within riparian corridors

Elephant use both of these corridors round the year because of altitude wise variation of rich fodder species. On the arrival of winter elephant's movement is towards lower areas like Chilla, Mundal, Khara, Shyampur and Chiriapur forest beats. At the same time elephants also utilize the adjoining forest of river Ganga, which is spread up to Rishikesh along the river Ganges. On the arrival of rainy season they migrate towards upper areas like in Luni, Pulani, Rawasan and Kasaan forest beats and this is the time when elephants start their long term migration towards Garhwal (Lansdowne) forest division. Many of the groups and solitary bulls use all of the forest beats for their local movement. During the summer elephants also use the Gohri forest range, which is in the north of the Chilla forest range to fulfill their various routine requirements.

Elephants also use the Ghasiram and Mundal water streams for visiting to river Ganges especially when their local movement is frequent in and adjoining forest beats, which are attached to river Ganges along with few bridges, which are in Ganga canal of Chilla hydro electric power plant. Few of the groups were also reported to use the Shyampur and Chiriapur forest ranges of Hardwar forest division during rainy season as east Ganga canal is fulfilled with water during that period. It is interesting to mention here that currently only bull elephants are crossing this track whereas no groups were reported during last 2 years. As per last four year data, groups of the elephants were reported in the same area but rapid developmental activities has restricted the frequent movement of elephant's group towards river Ganga in this part.

Few of the major reasons affecting local movement of the elephants in rainy season are:

1) During rainy season the elephants were seen moving towards upper areas of the park. This is because the low lying areas become swampy and unfit for free movement of the Elephants.
2) Another major factor contributing to their upward movement is the abundance of a blood sucking fly locally called as "daans" in low lying areas which irritates these elephants by hovering around their ears and trunk. This fly is commonly found affecting the cattle stock of Gujjars.
3) Forest fire is also one a factor to force the Elephants movement to a separate area where fire had not been so extensive. This fire if spread extensively then the movement of such a large animal also restricts to the same area for some time.

Impact of heavy floods during 2007

Initial observation suggested that a large extent of the Chilla forest was effected from the impact of heavy floods during July, August and September, 2007. On one side floods has affected the migrational pattern of elephants and on the other hand disrupts the natural regeneration potential of several grass species those grow especially in between dry river beds.

Effects on vegetation

Annual water stream beds inside the RNP area generally comprises of several fodder grass species like *Saccharum munja*, *Saccharum spontaneum*, *Desmostachya bipinnata* and *Cynodon dactylon*. All of these species are the favourite food item for elephants. Besides, few tree species those grow generally nearer to the Gangetic plains like *Acacia catechu, Dalbergia sissoo, Bauhinia variegata, Albizzia lebbek, Ehretia laevis* and *Lagerstroemia parviflora* were also damaged due to heavy floods. Mundal valley consists of larger feeding grounds (grassy patches) but this environmental event has destroyed whole of the area. Water flow has also caused damage to some extent in higher slopes of the protected area. Grass species which grow in profusion in higher altitude area like *Neyraudia arundinacea* were severely affected due to floods.

Effects on fauna

At the onset of winter (October onwards) elephant starts to migrate in lower forest pockets from high elevations but onservations suggested that elephant's migration rate may be slower as comparision to few previous years. It was revealed that few of the solitary bulls and groups, which utilizes whole of the area round the year, leaved the forest during the course of floods and migrated towards the adjoining forest of Garhwal forest division and Hardwar forest division. Even we have recorded the upper side movement of carnivores (*Panthera tigris* and *Panthera pardus*) and herbivores (*Muntiacus muntjak*, *Axis axis* and *Cervous unicolor*).

Developmental activities

1. *Agriculture expansion*

Increasing agricultural land use practices in the recent past have reduced the area that was once available to the elephants in Shivalik foothills. As wild foraging areas become increasingly less available to elephants, their depredations to the croplands is increasing regularly in many areas.

2. *Habilitation*

Human settlements in and around the park area have created the shrinking of elephant's natural paths. The human population around the RNP alone has doubled during past one decade and rapid urbanisation and industrialisation has resulting in the loss of many forestlands to townships and to various development related activities. Rapid enhancement in population born human settlement programmes includes the rehabilitation programme of the Tehri Dam evacuates, has lead to a very rapid, building construction work near to the forest area. And when a few constructions are build up, naturally the human beings inhabiting in these areas, starts clearing the nearby forest area for their biological, social, economic and aesthetic requirements.

3. *Fuel wood collection*

Collection of fuel-wood by villagers is one of the major problems, as they sometimes fell down the juvenile trees or shrubs.

4. *Grazing and fodder collection*

Grazing by the cattle of Gujjars (in few of the areas where they still exist) within the forest range and collection of the fodder species by them is also one of the major problem, as they lopped the tree (which are having seeds and young branches) even like *Ficus bengalensis, Ficus religiosa, Ficus rumphii, Emblica officinalis, Bridelia retusa, Anogeissus latifolia, Aegle marmelos, Dendrocalamus strictus, Bauhinia variegata, Grewia oppositifolia, Lagerstroemia parviflora, Oogeinia oogenensis*, *Garuga pinnata, Schleichera oleosa,* and *Lannea coromendelica*, which are crucial for frugivorous birds and mammals and sometimes they also fell down the small trees. Few of the villages those are peripheral to the park area also use the forest resources to meet out their energy requirements and their cattle also graze these feeding grounds frequently.

5. *Non-timber forest produce collection*

Collection of non-timber valuable forest production like *Eulaliopsis binata* (Bhabhar grass), *Kydia calycina* (Pula), *Aegle marmelos* (Bel) etc. are also the causative agents.

6. *Presence of unknown people*

At times unauthorized visits of local people were also reported loitering in the park area. Probably such people are of questionable identity and are responsible for acts of poaching. These types of anthropogenic activities are more commonly seen in those areas, which are attached to park boundary.

7. *Religious places within the protected area*

Religious places like Goddess Mansa devi, Chandi devi, Sureshwari devi and Bilkeshwar temple are in forest areas. The visiting devotees and workers of the above-mentioned temples hinder elephant's movement. Several times it was also seen that many people enter the prohibited areas of the park and indulge in nefarious activities. Sometimes they were reported to play cards, booze, roam here and there, burst crackers and throw stones to shoo away the elephants or other wild animals. There are many instances when religious banquets on large scale are organised. Hoards of visitors disturb elephants that came to drink water in the after noon hours. As during last decades the general economic condition of people has bettered, this has leaded to increase in the purchase power, social interactions, tourists and religious activities of the people at all levels (Joshi and Joshi, 2006).

More than 6-7 lacs people visit Mansa devi temple every year. In other temple more than 50,000 people visit annually. The crowd is seen especially in the Shivratri and Sawan Purnima fairs. As per a data more than twenty lack people has visited this year to Hardwar area on the occasion of Sawan Purnima fair. Many other religious places are also situated within the park area and it was inferred from present investigation that when elephant herd is on move nearer to these areas their frequent movement is hindered by presence

of local people. During the present investigation it was also observed that in few of the places elephant's time budget has changed, which has caused irregularity in their natural activities.

8. *Military complex*

Settlement of military complex (346.6 hectare) including an ammunition dump based at Raiwala in Dehradun district is situated in the center of the park and covered by park ranges from both the sides. This army complex is adjacent to the famous Chilla-Motichur corridor area of the park and presently this route is denied for elephant groups but occasionally adult solo bulls are known to use this area.

9. *Railway track*

Presence of railway track is another major problem, which impedes elephant migration and frequent movement within their home range. 19 elephants are killed due to train accidents since 1987 besides many other wild animals like leopard, spotted deer, python etc. This track is 16 kilometers long and comprises of sharp bends through which train drivers are unable to look the elephants from a safe distance and most of the accidents were occurred during night hours and in dry season (Joshi and Joshi, 2000).

10. *Increasing land for civil and developmental work*

The decrease in the extent to wildlife habitat is largely because of increase in human population and the resultant demand for more land. In many of the places those are peripheral to the park area, construction work is regularly on increase, which leads to the shrinkage of elephant's corridors.

13. *Running traffic*

The motor roads which are adjacent to the forests like Hardwar-Dehradun National Highway in Hardwar and Motichur forest ranges, Hardwar-Bijnor National Highway in Shyampur and Chiriapur forest ranges, Chilla-Rishikesh motor road and Hardwar-Laldhang motor road are few of the road networks, which consists of too much heavy traffic passes in between them. As both the sides of these road network comprises of protected area, therefore, elephants use these roads to inter change their traditional forest areas.

14. *Weed proliferation*

Few of the herbs and shrubs, which are replacing the forest vegetation rapidly are – *Parthenium hysterophorous, Lantana camara, Cassia tora, Cannabis sativa, Pogostemon benghalensis, Sida rhombifolia* and *Ageratum conyzoides*. These are never used by wild animals as their fodder, and on the other hand these are spreading very fast, reduces the other area in the forest. Weeds like *Parthenium hysterophorous* was more dominant in Motichur forest beat and distributed all over the site. In the month of October and November it shows flowering as well as fruiting stage, while in the month of December and January, it is in seed dispersal stage (Joshi et al., 2000).

15. *Forest fire*

Another major impact on the conservation of the elephant is forest fire. The periods from mid-March to June are called to be the fire season and this fire may be of natural or of anthropogenic origin. Sometimes burning cigarettes, biddies, matchsticks, electric fence etc. are also the causative agents of forest fire but sometimes this fire also took place naturally. When the upper surface of the land is too much hot the dry grasses like *Eulaliopsis binata* (Bhabhar grass) due to highly flammable nature sometimes catch fire on account of smallest negligence of human beings around. Few of the villagers are also responsible for this fire because they think that after burning of old vegetation new seedling of the trees come up quickly with better regeneration potential.

16. *Human-elephant conflict*

The factors that contribute to the killing of humans by elephants are the presence of villagers inside the forest area. Between the years 1980 to 1990, elephants in Rajaji – Corbett parks, killed 70 people. Such incidents appear to be increasing because 44 of these occurred between the years 1986 to 1990. Similarly, between years 1988 to 1999, elephants has killed 39 persons and injured 5 persons in and around the RNP area. In Hardwar forest range of the park elephants has killed 24 persons and injured 11 persons in between year 1985 to 2001.

17. *Impact of heavy flood during 2007*

The heavy floods of July, August and September, 2007 that impacted the riparian wildlife corridors and movement related activities of Asian elephant (*Elephas maximus*) represent a catastrophic environmental event in Shivalik foothills.

18. *Presence of Gujjars*

Gujjars are the nomadic community whose members stay inside the forest in huts. Gujjar rehabilitation programme is still ongoing in the RNP and till today out of nine, five forest ranges are completely freed from them. But Gujjars are still existing in the Hardwar forest division and are currently utilizing all the waterholes and fodder resources frequently for their routine requirements as the result of which few forest patches are rapidly replaced by toxicious weed like *Parthenium histerophorous* (Gajar grass) and *Lantana camara* (Lantana / Kuri jhari). Elephants must scarify the ground in order to feed on the short grasses due to domestic buffaloes being grazed. In this type of situations elephants are diverting themselves to the peripheral forests or they are performing their outside movements towards the agriculture fields, which generally lead to crop depredation by elephants.

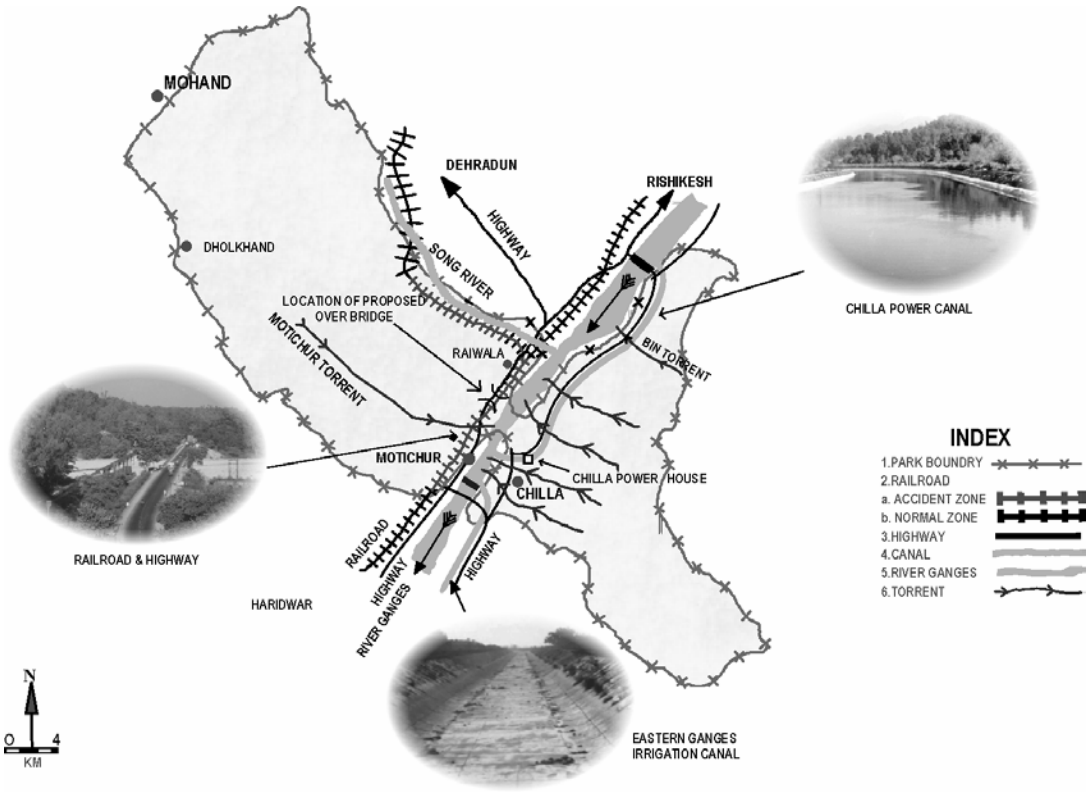

Figure 1. Map of the study area.

Figure 2. Bull elephants walking along the Hardwar – Bijnor National Highway at Shyampur forest.

Discussion

Since Independence, forest were cleared and felled and bought under the plough on a large scale. Construction work along with developmental activities like establishment of hydro-electric power plants, irrigation canals and national highways entailed deforestation of large tracts and colonization brought in its wake have resulted in a significant shrinkage in the habitat of wild animals (Singh, 1969). Presently most of the elephant habitats are destructed by various developmental activities or for human need purposes. There has been rise in competition among the same species for the food, shelter and other basic requirements. The status of the elephant in the adjoining countries is equally poor. Nepal, which has the lowest country population, has lost over 80% of its elephant habitat on account of human settlement. Bangladesh, Myanmar, Cambodia, Vietnam, Laos and Sri Lanka are also losing rapidly the natural forest cover, specially the elephant habitats. In Thailand in spite of the elephant having been a protected species since the 18th century, over exploitation of the habitat and the pressure of human population has made the species highly vulnerable (Daniel, 1996).

The population of wild Asian elephants has a discontinuous distribution in the northern, eastern and southern forest ranges in India. In the past the elephant population of the north used to migrate freely from one end to the other from the river Yamuna to the river Brahmaputra, traveling a maximum distance of approximately 1,300 kilometers as per their requirements in the foothills of Himalayas (Singh and Sharma, 2001). All the major habitats of elephants are very close to perennial rivers that fulfill their water requirements. This entire belt has comprised of all those fodder plant species that elephants like. Elephants do not have a fixed territory, but they show various territorial behaviours according to the season and availability of natural food and water. RNP and its adjoining forests are playing an important role in the conservation of elephants especially after the rehabilitation of Gujjar community.

The Chilla – Motichur corridor and Khara – Anjani corridor linking the Chilla forest with Motichur forest and Shyampur forest are subjected to severe anthropogenic pressures. Livestock grazing, fuel wood collection and movement of people are the major activities observed in both corridors. These anthropogenic activities have substantially affected the movement of elephant within their home range and have led to the loss of forests connectivity. Grazing by cattle has altered the feeding grounds and has led to increase in exotic weeds. Fishermen were also reported within these corridors in early morning and evening hours when elephants are more active. They used to cross the Ganges with the help of rubber tube and stay inside the island while moving inside the forest.

Corridors are important conservation tools and need to be preserved to ensure the genetic flow between the populations. If these corridors has got turned to shrink, inter-breeding will be replaced by intra-

breeding, which may led to loss of genetic material even for wide ranging wildlife species. Land use conflicts have intensified especially in those areas where wildlife movements are more common outside the protected areas. Human habitation and expanded agricultural activities between both of these corridor areas have already increased the number of incidents of conflicts between local communities and elephants. Similar phenomena are very likely to occur in few other internal corridors. Uncontrolled fishing, collection of fuelwood, grazing by cattle and encroachment along the forest edge and river Ganga will ultimately prevent the movement of elephants and other wild animals in this part. The long-term effects will include genetic isolation, habitat degradation within different reserves and intensify the conflicts between villagers and wild animals.

A large mammal like the elephant could be expected to move more considerable distances even with a short period and families of a clan seemed broadly coordinated in their seasonal movements (Sukumar, 1989). In the dry months i.e. from January to April, when no rainfalls occur, the groups seek the neighbourhood of streams and shady forests. From the month of July, after the first shower, they start roaming and feed on the fresh grass. This grass in hill tracts become long and coarse by July and August, the elephants then show their upward movements. The reason for the elephants and other animal's migration is the high lands, continuous and uninterrupted hilly terrain for grazing, assured food, ideal breeding ground and thick population (Sinha, 1981).

The long-term effects will include genetic isolation, habitat fragmentation within the same forest and enhancement in the human-elephant conflict in adjoining areas. Genetic isolation of elephant populations may also increase the chances of replacement of interbreeding to intrabreeding, and thereby reduce the population persistence even for wide ranging wildlife species.

The creation of corridors between two reserves has been proposed to minimize the genetic effects of isolation (Diamond, 1975; Dendy, 1987). Large and medium sized herbivores and carnivores largely depend on corridors for exchange of genes between populations and to search for seasonal foraging grounds and water. Loss of forest cover due to agriculture expansion and construction related work is responsible for the loss of forest connectivity between forested areas in the Nilgiri Biosphere Reserve (Sukumar, 1990). Although the importance of corridors has been accepted widely for management of wide ranging species, only a few studies have been carried out on the impact of human interferences on habitat corridors in India (Johnsingh et al., 1990).

The results from this study provide a sketch of the extent and likely development of human-elephant conflict in Shivalik foothills, major threats with some management measures. The RNP and its adjoining area is an important biological area and has great potential for wildlife and its conservation. People are also increasingly utilizing these old hamlets and as a result management of crop raiding by elephant is often uncoordinated and complicated. It is therefore appropriate to develop a scientific based protocol for conducting in depth analysis of these traditional corridors and serious human-elephant conflicts.

Management measures

1) During the course of elephant movement nearer to the National Highways, traffic should be stopped at a safe distance. At the same time people are not allowed to deter the elephants.
2) In Chilla forest elephants interchange the forest through a small bridge over to Ganga canal commonly known as Sony shroth. The bridge should be widened to some extent so that elephants may cross easily.
3) Ghasiram shroth is a traditional corridor in Chilla area and elephants utilize this track especially during dry months. During that period traffic of the Chilla – Rishikesh road should be stopped in evening hours.
4) Dudhia forest beat (island) and the islands situated in between river Ganges should be restored from any anthropogenic disturbances.
5) Grazing may be banned at least from the crucial areas of the corridors.
6) Habitat restoration may be planned to enhance forest cover in degraded areas. Besides, plantation of fodder plant species is also required.
7) Artificial water holes must be created, spread within the park area at short distance. For solving the problem water uplifting pumps will be used to uplift the well water during day hours, which will help during dry periods. Waterholes can also be connected with Ganga canal and management related practices should be carried out regularly.

8) As the park area mainly comprises of Dehradun / Hardwar region so it is proposed that the time of the night trains be shifted approximately half an hour earlier than the present schedule time. By employing this method the train could be made to move slowly and can be easily stopped in emergency, through the park area up to Hardwar.
9) Relocation of villages and Gujjar deras those are in the corridor area.

Acknowledgements

We are thankful to the Science and Engineering Research Council (SERC), Department of Science and Technology (DST), Government of India for providing financial support and thanks are due to Dr. R. C. Srivastava, Scientist 'G' and Dr. Jagdish Chander, Scientist 'F', DST, for their cooperation and valuable suggestions. Dr. U. Dhar, Director, G. B. Pant Institute of Himalayan Environment and Development, Kosi – Katarmal, Almora and Dr. R. K. Maikhuri, Scientist Incharge of the Garhwal Unit of G. B. Pant Institute of Himalayan Environment and Development are acknowledged for providing facilities, encouragement and suggestions. Shri Srikant Chandola, Additional Principal Chief Conservator of Forests (Wildlife), Government of Uttarakhand and Shri G. S. Pande, Director of the Rajaji National Park are acknowledged for giving the permission to carry out the research work in the said area. Thanks are to various concerned forest officials and staff for providing help during the field investigation.

Correspondence to:
Ritesh Joshi
G. B. Pant Institute of Himalayan Environment and Development,
Garhwal Unit, P. O. Box No. 92, Srinagar - Garhwal, 246174,
Uttarakhand, India
Telephone: + 91 1346 252603 (O)
E-mail: ritesh_joshi2325@yahoo.com

References

1. Daniel, J.C. 1996. Conservation of Asian elephant. Gajah. 16: 9-16.
2. Dendy, T. 1987. The value of corridors and design features of small patches of habitat. In: Nature Conservation: The role of Remnants of native vegetation, eds. G.N. Sanders, G.W. Arnold, A.A. Burbridge and A.J.M. Hopkins. Surrey Beatty & Sons. Pty Ltd., Sydney.
3. Diamond, J.M. 1975. The island dilemma: lessons of modern biogeographic studies for the design of nature reserves. Biological Conservation. 7: 129-146.
4. Johnsingh, A.J.T., and Williams, A. Christy. 1999. Elephant corridors in India: lessons for other elephant range countries. Oryx. 33 (3): 210-214.
5. Johnsingh, A.J.T., Prasad, S.N., and Goyal, S.P. 1990. Conservation of the Chilla- Motichur corridor for elephant movement in Rajaji-Corbett National Park areas, India. Biological Conservation. 51: 125-138.
6. Joshi, R., and Joshi, B.D. 2000. On the recurrence of rail accident death of an elephant (*Elephas maximus*) in Hardwar range of the Rajaji National Park. Him. J. Env. Zool. 14 (2): 123-128.
1. 7. Joshi, P.C., Joshi, R., and Joshi, N. 2000. Analysis of vegetation of a protected forest. Ecology, Env. and Cons. 6 (3): 345-349.
7. Joshi, R., and Joshi, B.D. 2006. Impact of anthropogenic activities on elephant (*Elephas maximus*) around few religious places: A case study from the Rajaji National Park, Uttaranchal, India. Him. J. Env. Zool. 20 (1): 87-90.
8. Kumar, D. 1995. Management plan of Rajaji National Park, 1995-96 to 2005-06. UNDP/WII.
9. Nowak, S., and Myslajek, R.W. 2005. Problems affecting migration corridors for large terrestrial mammals caused by the network of fenced motorways and express roads within the TEN-T programme: the situation in Poland. Report, The Association for Nature (WOLF), Poland.
10. Singh, A.P., and Sharma, R.C. 2001. Conflicts between linear developments and Asian elephants in sub-Himalayan zone of Uttaranchal. In: Ecology and transportation, eds. C.L. Irwin, P. Garrett and K. P. McDermott, pp. 423-432. Centre for Transportation and the Environment, North Carolina State University, Raleigh, NC.
11. Sinha, M.K. 1981. Elephant migration in Kaziranga. Tiger Paper. 8 (1): 16-18.

12. Singh, V.B. 1969. The elephant (*Elephas maximus* Linn.) in Uttar Pradesh. J. Bom. Nat. Hist. Soc. 66: 239-250.
13. Sukumar, R. 1989. The Asian elephant: Ecology and management. Cambridge University Press, Cambridge.
14. Sukumar, R. 1990. Ecology of the Asian elephants in southern India. II Feeding habits and crop raiding patterns. Journal of Tropical Ecology. 6: 33-53.